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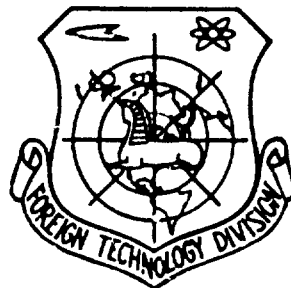
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Main stages of the development of observational and theoretical results based on the INTEROBS Program are considered.

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ABSTRACT

Principal results of research based on the SPIN Program are presented.

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Yuriy Alekseyevich Gagarin

(deceased)

Yuriy Alekseyevich Gagarin is dead. Life has been plucked from
the man who was the first in the world to blaze the way into outer
space, whose heroism, selfless devotion to the Motherland, and
courageous service to science will be an example for all those who
march in the first ranks of the explorers of the unknown.

Yuriy Alekseyevich loved life; he loved a joke.

On an occasion in 1963, at the end of a press conference, a
crowd of enthusiastic admirers surrounded the cosmonaut heroes. There
was handshaking, autographs...

At the press conference there was also the editor of the first
issue of "Artificial Satellite Tracking." In his briefcase there lay
a copy on which the editorial staff had just finished working.
Having written the note, "Dear Comrade Cosmonauts, with what words
can you wish the new edition on its way?," he passed it, together
with the magazine, to Gagarin.

Yuriy Alekseyevich turned over pages of the magazine, smiled
his remarkable, long-remembered smile, and wrote, "We bless you for
life — Gagarin." The blessing was supported also by his fellow
cosmonauts, P. R. Popovich, V. F. Bykovskiy, A. G. Nikolayev, and
G. S. Titov.

Thus was born the autograph of the esteemed editorial staff
of our magazine reproduced on the frontispiece.

Yuriy Alekseyevich perished at the dawn of his creative forces.
The news of his tragic demise went to the hearts of many millions
of people in the whole world, to whom the conquests of science are
precious. The memory of Yu. A. Gagarin will live throughout the
centuries.

Editorial Staff

TEN YEARS OF INTERNATIONAL COOPERATION IN THE FIELD OF OPTICAL TRACKING OF ARTIFICIAL EARTH SATELLITES

A. G. Masevich and N. P. Slovokhotova

(USSR)

An essay on the history of the organization
of optical tracking of satellites in the USSR and
of the development of international cooperation
in the field of scientific investigations based
on such observations.

October 4, 1957 — the first Soviet artificial earth satellite (AES) opened the space age, and up to the present time many hundreds of artificial bodies have been orbited. Each flying laboratory has made its contribution to the study of the world surrounding us and has made it possible to learn something new about the earth and the space surrounding it.

The instruments on board the satellites have aided in the study of the physical properties of the earth's atmosphere and the inter-planetary medium, magnetic fields and radiaticn belts, meteoric bodies in circumterrestrial space, the UV and IR radiation of the heavenly bodies, and fluxes of charged particles coming from the sun.

Meteorological satellites, active and passive communications satellites, and geodetic and navigational satellites are constantly at our service in space.

An impressive achievement of man's mind were spaceships, on which the first men into space carried out their research. The use of AES and space rockets with their scientific equipment mark a qualitatively new step of development for astronomy, physics, geodesy, geophysics, meteorology, biology, and many other sciences.

In the first days of the space age more than 200 optical space tracking stations over the earth began their difficult but interesting work. These observations, with the basic aim at that time of keeping track of the first space ambassadors in boundless space, gradually became a systematic multifaceted operation, conducted by diverse programs and sending valuable information for astronomical, geodetic, and geophysical observations.

As early as 1957-58 the Astronomy Council of the Academy of Sciences of the USSR [AC AS USSR] established cooperation in the field of optical tracking of AES with many countries of the world.

In 1958-59, stations on five continents — Europe, Asia, Africa, North and South America, and Australia — took part in the tracking of Soviet satellites.

The first foreign observations of the booster for the first AES reached the AC AS USSR at the beginning of October 1957 from the school observatory in Rodewisch (East Germany) and the Royal Astronomical Observatory in Edinburgh (Scotland).

In 1960-61, in connection with the end of operations on IGY and IGC programs, many foreign stations were shut down. At present, the Soviet Union receives regular observations from 16 countries: England, Bulgaria, Hungary, East Germany, the Netherlands, Italy, Cuba, Mongolia, Mali, the United Arab Republic, Poland, Rumania, France, Finland, Czechoslovakia, and Sweden.

In the past 10 years the Soviet computer center "Kosmos" has received more than one million results of tracking about 700 Soviet and American satellites and their boosters. Many precise observations have been received from Bulgarian, Finnish, Polish, Dutch, and Italian stations.

A. G. Masevich, Deputy Chairman of the AC AS USSR. Chairman of the Commision on the question "Scientific Research Using Tracking of Artificial Earth Satellites."

GRAPHIC NOT REPRODUCIBLE

All data from visual trackings are used in the ephemeris service and are published in the bulletin Results of Observations of Artificial Earth Satellites published by the AC AS USSR. In the past 10 years about 100 issues of the bulletin have been published.

The stations make their observations mainly using uniform methods and instruments. In the USSR and the other socialist countries visual observations are carried out using the AT-1 satellite telescope (d = 50 mm, field of view 11°, magnification 6×, maximum stellar magnitude 9^m), the TZK binocular (d = 80 mm, field of view 7°, magnification 10×, maximum stellar magnitude 10^m), the BMT-100 binocular (d = 110 mm, field of view 5°, magnification 20×, maximum stellar magnitude 11^m), and other instruments. Photographic tracking is done mainly using UFISZ-25-2 cameras with a Uran-9 objective (d = 100 mm, f = 250 mm).

Ten years' experience has made it possible to considerably improve the trackings and increase their accuracy. Station observers have introduced and realized many interesting innovations. Station operating experience and suggestions for improving the observations are published regularly in the Bulletin of Artificial Satellite Optical Tracking Stations published by the Astronomy Council. Fifty issues of this bulletin have been published in the past ten years.

Visual satellite tracking data from the USSR and cooperating countries are processed at the "Kosmos" computer center and are used basically for the ephemeris service. These observations are used to

determine satellite orbital elements, study their change, and then calculate the ephemerides used for subsequent satellite tracking.

But the ephemeris service is only one of the users of visual satellite tracking which, though photographic trackings are more accurate, because of their great number and rapid processing are an important source of data for solving a number of scientific problems.

In 1964-65 the COSPAR Working Group on Satellite Observations made a detailed analysis of the possibility of using visual satellite tracking for scientific purposes. The results of the study showed that visual trackings, if the object of observation is correctly chosen, are very valuable for the study of density changes in the upper layers of the atmosphere caused by changes in solar activity. This problem has at present become particularly pressing because of the increased solar activity in 1967-68.

However, the accuracy of visual tracking is not sufficient for investigating the detailed structure of the earth's gravitational field, for solving geodetic problems by methods of space triangulation, or for studying irregular changes in the density of the upper layers of the atmosphere.

Photographic observations of artificial satellites are more accurate.

Ye. Z. Gindin, organizer of the Soviet optical satellite tracking station network.

As early as 1958 we began to use, for photographic tracking of bright satellites, specially reconstructed NAFA-3s-25 (d = 100 mm, f = 250 mm) and NAFA-MK-75 (d = 210 mm, f = 750 mm) air survey cameras. These were equipped with high-speed shutters whose openings and closings could be recorded with great accuracy on chronographs.

The fast movement of satellite images on the photographic emulsion led to a very low exposure time, hundredths of a second for most existing satellites. To increase this time required that the telescope or its film holder follow the movement of the satellite. Telescopes used for ordinary astronomical observations do not have the equipment to permit them to move at such high speeds as are required for satellite tracking.

A number of improvements were proposed for cameras in order to raise their efficiency. These included such devices as M. K. Abele's scanning film holder, designed in Riga, L. A. Panayotov's camera with moving film, from the Main Astronomical Observatory of the AS USSR, and others.

The cooperating countries also proposed a number of designs for cameras to track satellites photographically.

In recent years, using the NAFA-3s-25 camera as the base, there has been developed the UFISZ-25-2 automatic field equipment set which has been installed at many stations in the USSR and other countries.

A new step in photographic tracking was the introduction, in 1967, of the AFU-75 camera (d = 210 mm, f = 750 mm), designed by K. K. Lapushka and M. K. Abele (Riga). The camera can reliably record the scintillations of active geodetic satellites and can photograph the passage of passive satellites of up to 8-9 stellar magnitudes.

A number of stations are equipped with the SBG general-purpose instrument for photographic satellite tracking (d = 500 mm, f = 760 mm), produced by the VEB Karl Zeiss (East Germany).

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In 1968 we will introduce, at the Zvenigorod experimental station, the first model of a new automatic triaxial satellite camera for photographing weak — up to 10 stellar magnitudes — artificial space objects (d = 500 mm, f = 700 mm).

By 1962 the optical tracking of artificial satellites in the USSR and cooperating countries reached a considerable level. Scientific investigations based on such observations intensified. All conditions were ripe for converting to multilateral cooperation among the participating countries.

On March 14-17, 1962, at a meeting in Warsaw, the representatives of the Academies of Sciences of the socialist countries decided to create a Commission on Multilateral Cooperation Between the Academies of Sciences of the Socialist Countries on the question "The Optical Tracking of Artificial Satellites," which, on a proposal by Polish scientists in 1965, was renamed the Commission on the Question "Scientific Research Using Artificial Satellite Observations." The leadership of the Commission was entrusted to the AC AS USSR.

On November 27, 1962, the first coordination meeting of the Commission took place in Leningrad; representatives from Bulgaria, Hungary, East Germany, Mongolia, Poland, Rumania, the Soviet Union, and Czechoslovakia participated in the meeting. In accordance with the recommendations of this meeting, the Commission will conduct working sessions at least once a year, in various countries, usually simultaneously with scientific conferences of satellite observers.

By the end of 1967, 11 meetings of the Commission had been held; these occurred in the USSR, Poland, Hungary, East Germany, and other countries.

At the present time the Academies of Sciences of Bulgaria, Hungary, Vietnam, East Germany, Mongolia, Poland, Rumania, the USSR, and Czechoslovakia conduct joint observations of satellites according to a unified program, exchange observation results and other material obtained during collective operation, process the obtained results by various methods, conduct joint research using newly created

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AT-1 telescope.

equipment according to coordinated programs, and publish the result of cooperative efforts and bibliographic handbooks.

Courses are conducted to prepare artificial satellites observers.

Since 1963 the cooperating countries have published jointly the international almanac "Observations of Artificial Earth Satellites," in which are published scientific articles, remarks on station operation, and news items from scientific meetings. Issues of the almanac have been prepared in the USSR (1963), Poland (1964), East Germany (1965), Czechoslovakia (1966), and Rumania (1967). The next issue is being prepared in Bulgaria.

Multilateral scientific cooperation is being carried out on the following themes.

1. Visual satellite tracking for purposes of the ephemeris service. This work is carried out by the Academies of Sciences of all the cooperating countries. The coordinator is the AC AS USSR.

The visual satellite tracking stations in the cooperating countries conduct observations, process them operationally, and report them to the computer center. These observations are used to calculate the ephemerides for both visual and photographic tracking based on various programs. The ephemerides are computed at the "Kosmos" computer center, and also by computer centers in Poland and Czechoslovakia.

TZK binocular.

2. Basic visual observations of low-flying satellites in order to study temporary variations in atmospheric density (the INTEROBS Program). Participatants include the Academies of Sciences of Bulgaria, Hungary, East Germany, Poland, Rumania, the Soviet Union, and Czechoslovakia. The coordinator is the Hungarian Academy of Sciences.

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The INTEROBS Program provides for simultaneous visual tracking of low-flying satellites from two or more stations. Such observations make it possible to obtain certain instantaneous satellite orbital elements and their changes, and from them to study the temporary variations in atmospheric density. This program was proposed by observers in Hungary and East Germany and first tried in April 1961.

3. Synchronous photographic satellite tracking for purposes of triangulation. Participants include the Academies of Sciences of Bulgaria, Hungary, East Germany, Cuba, Mongolia, Poland, Rumania, the Soviet Union, and Czechoslovakia. The coordinator is the AC AS USSR.

Synchronous photographic tracking under the program for space triangulation makes possible geodetic communication between points on the earth's surface which are far from one another. This method is very promising for solving a number of practical problems. It can be used for geodetic conformation of aerial photographic surveys in remote regions, the geodetic connection between islands and continents, etc. Space triangulation will make it possible to measure the distance between the points separated by the ocean, which henceforth will serve as a basis for solving problems of the movement of continents; the simplicity of the method makes it possible to carry out the operations comparatively rapidly and with low financial outlay. The method can be extremely valuable for developing countries, those with particularly vast territories, during their mapping in order to locate natural resources.

The method of space triangulation based on satellite observations was proposed and tested in 1961 by the Pulkovo astronomers.

The first session in 1961, in which the stations of Pulkovo, Nikolayev, Khar'kov, and Tashkent participated, showed that this method gives an accuracy of no worse than ±80 m.

BMT-110 binocular.
Tashkent Station
No. 1052.

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In May-June 1963 the first session for synchronous photographic observations of the Echo-1 satellite took place; participants included, besides Soviet stations, stations in Potsdam (East Germany), Prague (Czechoslovakia), Bucharest (Rumania), and Poznan (Poland). The total extent of this measuring network was more than 10,000 km.

In subsequent international sessions for synchronous photographic observations considerable observational data were obtained; these were successfully processed in the USSR, Rumania, Poland, Bulgaria, and East Germany.

Two sessions — in 1965 and 1966 — were conducted in order to establish communication between European stations and African stations in Bamako (Mali) and Cairo (United Arab Republic). The first session was not completely successful due to poor weather at the European stations; during the second, however, much data were obtained for setting up geodetic communication between Cairo and the European stations.

Since synchronous observations of objects higher than the Echo satellite can increase the number of stations participating in the operation and thus increase the reliability of the space triangulation network, it was decided to study the possibility of observing the high-altitude satellite Pageos. For this purpose, in 1966 and 1967 observation sessions were organized; participants included stations in Bulgaria, Hungary, Italy, Mongolia, Poland, Rumania, the Soviet Union, Czechoslovakia, and also stations in Cairo and Bamako. During these sessions, synchronous pairs of observations were obtained at the stations Cairo-Zvenigorod (3000 km), Cairo-Poznan (3000 km), Cairo-Riga (3500 km), Cairo-Bamako (3500 km), Cairo-Pulkovo (3800 km), Nikolayev-Bamako (5000 km), and Zvenigorod-Bamako (6000 km).

The Riga and Uzhgorod stations, beginning in 1966, have participated in international observations of American active geodetic satellites of the Geos type in conjunction with the program of the Smithsonian Observatory, together with stations in Western Europe, Asia, and the United States. In 1966 the station in Riga (observer — K. Lapushka) obtained 29 photographs of scintillations of the Geos

satellite, of which 11 were synchronous with a number of stations in Western Europe.

4. Improvement of the equipment used for satellite tracking. The Academies of Sciences of East Germany, Poland, the Soviet Union, and Czechoslovakia are participating in this.

The improvement of cameras for satellite photography, the development of new instruments, and also the exchange of these instruments are constantly being worked on in order to increase the quality of observations and to unify the results obtained in the cooperating countries.

The Academy of Sciences and the Central Administration on Geodesy and Cartography of Czechoslovakia have designed a camera with a Telikon objective for satellite photography. One sample of this camera was sent in 1965 for research in the Soviet Union and one model was sent to Poland.

VFISZ-25-2 Satellite Camera. Nikolayev Station No. 1077.

GRAPHIC NOT REPRODUCIBLE

The Academy of Sciences of East Germany has sent to the Soviet Union and Bulgaria two cameras, made in accordance with a design from the Geodetic Institute in Potsdam for observations of Laplace azimuths in the program used by German scientists.

The Academy of Sciences of the USSR has sent to the Academies of Sciences of Bulgaria, Hungary, East Germany, Cuba, Mongolia, Mali, the United Arab Republic, Rumania, Poland and Czechoslovakia a set of improved UFISZ-25-2 cameras with automatic control.

For several years now, within the frameworks of multilateral cooperation, there has been under development a special camera for photographing artificial earth satellites. This is the SBG general-purpose instrument (d = 500 mm, f = 760 mm), which is controlled using programs fed through a special computer. The VEB Karl Zeiss (East Germany) has already begun serial production of such a camera. The Academies of Sciences of the cooperating countries have ordered from East Germany such cameras for their stations, which will make it possible to carry out investigations requiring observations of particularly high accuracy.

Above we have already mentioned Soviet work in the designing of cameras for photographing artificial earth satellites.

Photo of passage of Echo-2 on first orbit after launch. NAFA-3s-25 Camera. Dushanbe Station No. 1068.

GRAPHIC NOT REPRODUCIBLE

5. Photometric satellite observations. Coordinators — the Academies of Sciences of the USSR and Czechoslovakia.

Photometric observations of artificial satellites have been carried out in the USSR since 1958. Since most satellites do not have regular spherical form, their brightness (due to rotation of the satellites around their axis) changes and thus it becomes possible to determine the period of their rotation above their axis.

Systematic photometric observations make it possible to study regularities in the change of the period of rotation caused by atmospheric braking, and thus to investigate the state of the earth's atmosphere and the influence of variations in solar activity on it.

The USSR and Czechoslovakia are also making photometric observations of satellites as they enter the earth's umbra. Such observations make it possible to study the distribution of ozone and aerosols in the atmosphere. Electrophotometric instruments that permit us to observe light reflected by the satellite in various regions of the spectrum have been especially created for such investigations at the Astronomy Institute of the Academy of Sciences of the Kazakh SSR (Alma-Ata) and of the Astronomy Institute of the Academy of Sciences of Czechoslovakia (Ondřejov).

In addition, multilateral cooperation is being carried out along the following lines.

6. Theoretical investigations, involving the scientific utilization of the results of satellite tracking (calculation of the orbital elements of the satellites, investigations in the field of satellite geodesy and geophysics). The Academies of Sciences of all cooperating countries are participating.

7. Joint publications on questions of optical satellite tracking. The Academies of Sciences of Bulgaria, Hungary, East Germany, Mongolia, Poland, Rumania, the Soviet Union, and Czechoslovakia are participating.

8. The compilation of bibliographies of literature on questions of optical satellite tracking. The Academies of Sciences of all cooperating countries are participating.

In recent years certain new types of cooperation have appeared:

a) Schools or courses for young observers in the cooperating countries.

On the initiative of the Soviet Union and upon recommendation by the Commission, such schools for young observers of the European and Asian countries were conducted in September 1965 in Tashkent and in October 1967 in Pulkovo. Participants included 70 students from Bulgaria, Hungary, East Germany, Poland, Rumania, the Soviet

SBG Satellite Camera
of the Potsdam Geodesy
Institute (East
Germany).

Union, Czechoslovakia, and Mongolia. The observers listened to lectures on basic questions involving the methodology of satellite observations using photographic cameras, methods for processing these observations, and the possibility of using the obtained results for scientific purposes. Under the leadership of experienced teachers they studied methods of working with the cameras, processing the negatives, receiving precise time signals, and calculating the ephemerides.

b) The organization of combined stations for the photographic tracking of satellites over the territories of the cooperating countries. This new form of conducting cooperative works was proposed by the Astronomy Council as a means for expanding international scientific cooperation. The Academy of Sciences of the USSR provides the station with scientific equipment and instructs the indigenous personnel of the station in observation methods. The results of the observations made at such a station are used by scientific organizations in the cooperating countries on an equal footing with other results.

In the last ten years of the space age, combined observations of artificial earth satellites in cooperating socialists countries, successful scientific investigations based on such observations, have strengthened the scientific bonds between observers and various countries and have prepared a solid foundation for solving new problems in research on the earth and in space.

THE HISTORY OF SYNCHRONOUS SATELLITE TRACKING

D. E. Shchegolev

(USSR)

Recollections about the first steps of
simultaneous photographic tracking of satellites.

It all started in January 1961, during a get-together of
satellite observers in Moscow. Late one night, in a room in the
"Moskva" Hotel, there sat three Leningraders — Yu. V. Batrakov,
A. A. Kiselev, and I — discussing various subjects. We taked about,
in particular, the unexpectedly high accuracy of observations
obtained using the NAFA-3s-25 cameras. When these instruments had
been made standard equipment for satellite tracking stations it was
assumed that they would guarantee an accuracy of no greater than
tenths of a minute of arc and tenths of a millisecond of time.
Actual practice showed, however, that the error can be decreased by
a factor of three and even by a factor of five. But for the ephemeris
service (at that time this was the basic user of the observations)
such high accuracy was not required. How could this accuracy by used
best of all?

And then Batrakov proposed the organization of simultaneous
tracking. The idea of this method was familiar, but an objection was
immediately raised; we were reminded of the difficulties encountered
by stations that attempted to synchronize camera shutters using control

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radic signals. But Kiselev sensibly noted that using our processing method it was not necessary at all to synchronize the shutters — the position of the satellite could be obtained by interpolation. At that time there was a suitable satellite, Echo-1. We decided to work out all the details (Weiss' works were not known to us at that time).

The next day we sat and pondered on this. Maybe there was something amiss, but everything seemed in principle to be very simple and well defined. This simplicity frightened us — might there not be unforeseen obstacles? We decided not to present our proposal about setting up such observations at the meeting, but to test this method using a simple experiment — what would we find?

We called some old friends: the former workers at Pulkovo F. F. Kalikhevich (Nikolaev) and A. A. Latypova (Tashkent), and we invited V. Kh. Pluzhnikov from Khar'kov and presented the idea of our experiment. We would determine, from observations of Echo 1, the location of Khar'kov, using the other three stations as our reference points. The idea was pleasing. We decided to try it, and we all went our separate ways.

At Pulkovo we prepared the first program for synchronous observations (by the way, it was so successful that its basic premises have been retained even to the present time) distributed to the stations, and set up a session at the end of April 1961. The time came for the session, and, as if we were doomed to failure, it began to rain, not only in Pulkovo but even in Tashkent! During the infrequent clear hours we managed to track the satellite in fits and starts; we had a feeling of hopelessness: there were few negatives, the satellite disappeared from view, the white nights approached...

But when the session ended, it turned out that the results were not as bad as we had anticipated: there were 44 negatives and 14 synchronous groups. The processing of this data, it is true, took almost a year, since we had to refine the processing method, something new had to be invented. Nevertheless, at the next conference, in

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Riga in 1962, we could publicly state that synchronous observations of Echo 1 using standard equipment were not only possible, but even were quite accurate — of the order of ±50 m.

Thus synchronous photographic satellite tracking emerged from the experimental stage and within the period of one year became the basic type of operation of photographic stations in the USSR and cooperating countries.

THE SCIENTIFIC USE OF QUASI-SYNCHRONOUS VISUAL SATELLITE TRACKING DATA

M. Ill

(Hungary)

Main stages of the development of observa-
tional and theoretical results based on the
INTEROBS Program are considered.

1. Introduction

During the first years of satellite tracking the main purpose
of visual observations was to provide data for the computer centers,
i.e., the observations served mainly for an approximate determination
of satellite orbits and ephemeride calculations. Soon, however, it
became apparent that visual tracking also contains valuable
scientific information. In particular, interesting scientific results
could be drawn from quasi-synchronous visual trackings.

1.1. The Characteristics of Quasi-Synchronous Observations.

By quasi-synchronous observations we mean those measurements
which were conducted from two or more stations at the same period of
time, while the individual measurements (within this time period)
were carried out, generally speaking, at various moments.

The method of quasi-synchronous observations was proposed in
particular for determining atmospheric density, and is therefore
based on systematic calculations of the satellite's circling time.

The remaining orbital elements of the satellite were either not calculated at all, or were determined with a relatively low accuracy. Thus, unlike classical methods, the method of quasi-synchronous observations does not calculate the 6 interrelated orbital elements. It is most simple to determine the circling time by noting 2 moments of passage of the satellite across a selected portion of the sky.

An important feature of quasi-synchronous observations is the need for obtaining, at a given interval of time, a maximum number of positions of the satellite (5-25 positions per minute), i.e., to always obtain an individual "chain" of observations. From among these dense sets of positions it is easy to isolate the synchronous pairs — the topocentric coordinates of the satellite from two or more stations, related to the same given moment of time. It is important to note that even one single synchronous pair of coordinates defines the position of the satellite in space uniquely. Completely new processing methods can also be applied to synchronous pairs of coordinates. For example, instead of the topocentric directions (α, δ) the topocentric or geocentric distances can also be used.

Of important significance is the fact that we can calculate specific parameters from each single position of the satellite in these "chains" of observations, independently of the others, and examine the average of the single results as the most probable value. Since in this case the same parameter is calculated 20-60 times, the determination accuracy is considerably increased [1].

1.2. <u>Organizational Questions</u>.
After setting up a fundamental theory for conducting and processing quasi-synchronous observations [2], we made detailed observations and on the basis of this first positive experiment there was organized observer cooperation for carrying out quasi-synchronous observations (the INTEROBS Program). The stations participating in the INTEROBS Program made their first detailed observations in August 1963, while since 1964 there have been regularly carried out specially organized observation sessions. Each such session lasts ordinarily 10-20 days.

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Cooperative efforts under the INTEROBS Program were organized
by the Hungarian Academy of Sciences and the Astronomy Council of
the Academy of Sciences of the USSR. Participating stations were
supplied with ephemeris telegrams from the "Kosmos" Computer Center
(Moscow).

The number of satellite positions obtained within the INTEROBS
Program is as follows:

> 1963 — about   600 positions,
> 1964 — about   6,400 positions,
> 1965 — about 12,200 positions,
> 1966 — about 40,000 positions.

All observations were sent to the operating coordination center
(Baja, Hungary). Here the synchronous part of the observations was
selected and all data were prepared for further processing (arranged
in chronological order, etc.). Appropriate observations were
p blished by the Hungarian Academy of Sciences [3, 4, 5, 6] and
presented to the participants in the program for use.

2. The Processing of Quasi-Synchronous Observations.

Quasi-synchronous observations make it possible to create
completely new processing methods. The first processing was done
using the method published in [2], which consists of many independent
stages. It appeared, however, that this initial method is not the
only possible one or the best one from all points of view. Since a
number of organizations took part in the data processing, several
methods were proposed. Thus, in the quasi-synchronous observations,
not only the observations but also the processing methods are the
result of collective work. Below we will give a brief survey of
the individual processing stages.

2.1. Determination of Synchronous Paris of Coordinates.

The first stage in the processing is to obtain from the
quasi-synchronous observations synchronous pairs of coordinates (i.e.,
topocentric coordinate pairs, pertaining to the same moment of time).
This problem can be solved by simple linear interpolation [2]. Study
showed that the subjective error in interpolation leads to a radius-

vector error of the order of ±1 km [7].

Although this result is quite satisfactory, to process a great
deal of data it is necessary to develop methods which can be programmed
on electronic computers. One of the possible methods is to represent
the observations of one station in the form of a cubic polynominal
in the following form [8]:

$$\alpha = A_0 + A_1(t-t_1) + A_2(t-t_1)^2 + A_3(t-t_1)^3$$
$$\delta = D_0 + D_1(t-t_1) + D_2(t-t_1)^2 + D_3(t-t_1)^3 \tag{1}$$

Here t_1 is the time of the first measurement in a given series. The
coefficients A_i, D_i are calculated by the least-squares method.

2.2. Determination of the Coordinates of a Point Beneath the Satellite.

The satellite circling times necessary for determining
atmospheric density can be easily obtained from the moments of
passage of the satellite across a selected portion of the sky. These
moments are easily determined if we know the coordinates of the points
beneath the satellite.

The coordinates of a point below a satellite can be calculated
by various methods. A simple method applicable to measurements
conducted in the horizontal system is as follows [2].

First the satellite coordinates measured from the earth are
converted into geocentric coordinates. We then calculate the length
Δ_{AB} of the orthodrome connecting stations A and B, and the angles
α_A and α_B formed by the meridians of the stations with the orthodrome.
These auxiliary calculations are made one time only. We then obtain
the coordinates of the sub-satellite points by solving two spherical
triangles. The sub-satellite coordinates are obtained twice for
each synchronous pair of coordinates, which provides good control.
This method is applicable only in the case of two stations; if we are
using several stations it is necessary to form several pairs. The
entire calculation process can be done on electronic computers [9].

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Meeting of the chiefs of Soviet sta-
tions participating in observations
under the INTEROBS Program. Ryazan',
January 1967.

Another method, developed for observations obtained in an
equatorial system of stellar coordinates, can be used with any number
of stations [1]. Here we use the geocentric coordinate system
rotating together with the earth. In the case of three stations
(observation points), in addition to the 3 basic equations we
introduce 12 auxiliary equations and, using Legendre functions,
obtain finally the system of 27 ordinary equations. This system is
solved in a special manner so that as a result we must solve only a
system with 3 unknowns. As a result, we obtain the geocentric
coordinates of the satellite X_s, Y_s, Z_s, from which, using known
spherical formulas, it is easy to obtain the coordinates of the
sub-satellite point.

The next method also uses as its basis topocentric equatorial
coordinates α_1, δ_1 and α_2, δ_2, obtained from two observation points
[10]. We write, in the geocentric system, the equations of the planes
which satisfy the following conditions: a) Each plane contains one
of the observation points; b) The planes form, with coordinates of
plane XZ, the angles α_1 and α_2. The intersection of these planes gives
the geocentric coordinates of the satellite X_s, Y_s. The coordinate
Z_s is obtained on the line of intersection of the planes using angles
$90 - \delta_1$ and $90 - \delta_2$, respectively. Here, from the geocentric
coordinates of the satellite, we calculate the coordinates of the
sub-satellite point.

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In addition to the above-mentioned methods, the method of space triangulation [11] was also successfully used in calculating the geocentric spatial coordinates of a satellite. This method was also used for the case of horizontal coordinates [12]. In this case it was useful to use simultaneously 2 or 3 different methods.

2.3. Determining the Time of Passage of a Satellite Across a Selected Portion of the Sky.

When processing quasi-synchronous measurements, up to this time we have calculated, in most cases, the moment of passage of the satellite across a selected portion of the sky, since it is thus very simple to determine the quasi-draconic or synodic period of revolution. The methods used to determine the moment of passage can be divided into two groups:

1) Methods based on interpolation without using approximate values of the orbital elements.

2) Methods in which calculations are made on the basis of the assumed approximate values of the orbital elements.

In all cases, when this is possible, the moment of passage is calculated from each single sub-satellite point, and the average value of these results is examined as the most probable moment of passage [1].

2.3.1. The Moment of Passage Obtained by Interpolation.

If we have at our disposal at least two sub-satellite points, it is most simple to use linear interpolation (numeric or graphic) [2]. However, if there are a great many sub-satellite points, it makes sense to represent the corresponding moments of time t_i as functions of the geocentric latitude (or longitude) in the form of a third-power polynomial, and then, using the least-squares method, to calculate the moment of passage across a selected portion of the sky [13]. In both methods we disregard the fact that, in general, there are a large number of sub-satellite points, and that using this given process a definite role is played only by those points which lie near the selected portion of the sky. This disadvantage is

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eliminated by using the following method [14].

Let us assume that we have a series of interconnected parameters:

$$\left.\begin{array}{c} \varphi_1, \varphi_2, \ldots, \varphi_i \\ t_1, t_2, \ldots, t_i \end{array}\right\} \quad ; \tag{2}$$

where ϕ are the geocentric latitudes of the sub-satellite points. We first determine the velocity of the sub-satellite point along the entire long arc (beginning from the first point):

$$V_{1,2} = \frac{|\varphi_1 - \varphi_2|}{|t_1 - t_2|} \ , \qquad V_{1,3} = \frac{|\varphi_1 - \varphi_3|}{|t_1 - t_3|} \ , \ldots , \qquad V_{1,i} = \frac{|\varphi_1 - \varphi_i|}{|t_1 - t_i|} . \tag{3}$$

Using velocities $V_{1,2}$; $V_{1,3}$; $\ldots$; $V_{1,1}$ we wish to determine the velocity V_{1,ϕ_0}, i.e., the average velocity of the sub-satellite point in the interval $|\phi_1 - \phi_0|$, where ϕ_0 designates the selected parallel. This can be done, for example, graphically by representing the averaged velocities as a function of the latitude interval, i.e., $V_{\phi_1,\phi_k} = F(\phi_1 - \phi_k)$. From this curve it is easy to select the desired velocity V_{1,ϕ_0}. Using the velocity V_{1,ϕ_0} thus obtained, we find the time interval required by the satellite to cover the distance $(\phi_1 - \phi_0)$ to the selected latitudinal circle using the following formula:

$$\Delta t_1 = \frac{|\varphi_1 - \varphi_0|}{V_1} \quad ; \tag{4}$$

Consequently, the moment of passage T_1:

$$T_1 = t_1 + \Delta t_1 \quad ; \tag{5}$$

This procedure is repeated for each point and the time of passage is averaged every time. Naturally, the entire calculation process can be programmed, and for determining individual values of V_{1,ϕ_0} we can use the least-squares method or the Lagrange polynomial. It appears that this method can also be used in the case of the meridian, and even in well-known cases using any method it is more suitable to determine the times of the intersection of the meridian. It is best

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to determine the passage across the meridian when

$$\frac{d\lambda}{dt} > \frac{d\varphi}{dt} \ .$$ (6)

From this condition it follows that the latitude of the sub-satellite
point at which it is most favorable to determine the passage across
a longitudinal circle depends on the inclination of the satellite's
orbit and can be determined from the following formula:

$$\cos^2 \gamma = \frac{\cos^2 i + \sqrt{\cos^4 i + 4\cos^2 i}}{2} \ .$$ (7)

2.3.2. The Use of Approximate Values of Orbital Elements.

Since the approximate values of the orbital elements of a
satellite are often known, they can be used to calculate the time
of passage across a circle of latitudes [1].

From the sub-satellite points which we have at our disposal we
can determine, in a simple manner, the distance of each individual
point from the selected parallel. On the basis of the approximate
values of the orbital elements we can also calculate the average
values of the sub-satellite points on each part of the orbit. From
these data it is easy to calculate the time interval required by the
satellite to cover the difference in latitudes $(\phi_0 - \phi_n)$ using the
following formula:

$$t_o - t_n = \frac{R_{av}^2}{K\sqrt{p}} (\mu_o - \mu_n) \ ,$$ (8)

where R_{av} is the average radius-vector in the examined interval, $K =$
$= 631.35 \ km^{3/2}s^1$, p = orbital parameter, $\mu_0 - \mu_n$ = length of route
in the interval $\phi_0 - \phi_0$.

It appears that this method gets good results and can be readily
used when processing quasi-synchronous measurements. With slight
modification this same idea can also be used to determine the time
of intersection of the meridian. This is suitable when the satellite
orbit has slight inclination, and for all satellites near the apex
[14].

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All of the above methods have the advantage that they are very simple and therefore can be carried out using ordinary computer methods; on the other hand, they can be programmed, which is inevitable when there are a large number of observations.

2.4. Determining the Circling Time and Its Change.

From the observations, because of the geographic position of the observation stations, we determine the passage not across the celestial equator but across different latitudes. As a result we obtain not the true draconic period, but the quasi-draconic period. However, within limits of visual accuracy, it coincides with the draconic and can be easily recomputed in the sidereal period [1], [2]. When investigating changes in atmospheric density, however, it makes no difference whatsoever which period we use, since the nature of the changes is reflected identically in all periods.

2.4.1. The Method of Linear Changes of the Period.

The simplest method is that in which it is assumed that the change in rotation period between two observed passages of the satellite is linear. Since n — the number of revolutions in a given time interval — is known, the average period of rotation of the satellite can be calculated for each interval, determined from two observations, and the change in period per revolution can be calculated, correspondingly, from the two values of the period. The period itself was obtained by simply dividing the time interval (between two passes across a segment of the sky) by the number of complete revolutions $\bar{n}$. Changes in the period of revolution in one rotation can be determined in the future, for example, graphically. One possible way of doing this is to represent the calculating periods as a function of the number of revolutions (n) and smooth them [15]. From this curve we can take the periods and, correspondingly, their changes, for example, every ten revolutions.

According to another version, the period is determined graphically [16], by representing the calculated moments of passage across the selected segment of the sky as a function of time (revolutions). The ordinate of this graphic representation can be reduced considerably if we do not plot the actual moments of passage but their

Participants in the INTEROBS confer-
ence discuss tracking methods.
Ryazan', January 1967. From left to
right: program coordinator M. Ill,
M. A. Vaysov (Kazan'), V. I.
Kuryshev and Ye. Ye. Artemkin
(Ryazan').

reduced values: the remaining values are calculated using approximate value of the period with the aid of the following formula:

$$T_i = T_{\psi_i} - n\, p_\circ \, , \qquad (9)$$

where T_i is the ordinate of the curve, T_{ϕ_i} is the moment of passage calculated from observations, n is the number of revolutions, and p_0 is any approximate value of the period. From this curve the

period (and, correspondingly, its changes) can be determined from the following formula (for example, after each 10th revolution):

$$P_n = P_\circ + \frac{T_{i+10} - T_i}{10} ; \qquad (10)$$

2.4.2. The Graphic Method of Calculating Changes in Period.

To process satellite data we also applied the method used when studying variable stars [10]. It was assumed that in the examined interval the change in period is constant. By designating the observed passages of the satellite by O, we can calculate the difference $(O_n - C_n)$, which occurs after n revolutions with respect to the hypothetical period. This difference can be represented as a function of time; in the general case we get a parabola. From this curve we can determine the true period (which pertains to the initial epoch of the observation data). The change in period is connected with the values O - C by the following equation:

$$\Delta = \frac{dP}{dn} = \frac{2(O_n - C)}{n(n-1)} ; \qquad (11)$$

Therefore the averaged values of O - C are again represented graphically, viz.: 2(O - C) as a function of n(n - 1). In the event the change in period is actually constant, this representation gives a straight line. A break in the straight line indicates a

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sudden (abrupt) change in the period. A close distribution of the points reflects not the true changes in period (since during the derivation the change in period was assumed constant), but rather measurement errors. Such a graphic method seems suitable for determining, within an interval of several days, a sufficiently probable (constant) value of the change in period of revolution. This method is less suitable for temporary changes in period.

The numerical version of the method [7] gives the same results; however it reacts more sensitively to measurement errors.

2.5. Determining the Remaining Orbital Elements.

Determination of the remaining orbital elements has no practical significance for calculating changes in atmospheric density. Only the eccentricity e of the orbit and the longitude of the perigee ω should be known with some accuracy. Various methods have been proposed for determining them. Since in general there is always a great deal of observational data, it is best to use the method proposed in [2], in which a reliable solution is obtained by using the least-squares method.

It is also possible to obtain the eccentricity graphically from the known values of the "scale of heights" H, since there is an almost linear dependence between the change in the period of revolution and the eccentricity [17].

3. Results of Processing the Observations.

The observations were first processed in order to see whether the quasi-synchronous observations and the proposed methods are actually applicable. It was established that the use of interpolation methods when determining synchronous pairs of coordinates gives good results and that, for example, the calculated radius-vectors show, in general, a scatter of the order of 1-2 km [7, 12, 18]. Then it was shown that the orbital eccentricity cannot be determined by method [2] on a short orbital arc. On the whole it turned out, however, that the proposed methods satisfy the requirements of the operation and make processing possible.

The first changes in period and atmospheric density were calculated beginning in 1965 [10, 19, 12, 15, 20, 21]. These operations were conducted by various institutions, independently of each other, using the methods described above. In addition to these specific results presented in detail in the individual papers, we can establish the following general results:

a) The method of quasi-synchronous observations is suitable for determining and investigating temporary changes in atmospheric density. The beginning of a change in atmospheric density in a favorable case can be determined with an accuracy to 8-12 hours.

b) Quasi-synchronous observations make it possible to determine the period of revolution with an accuracy of about $\pm 0^m.001$, and its change with an accuracy of about $\pm 0^m.0001$. In a favorable case these values can be one order of magnitude better.

c) Quasi-synchronous observations under the INTEROBS Program were used to obtain changes in atmospheric density by 20%-90% for a period of 1-2 days.

4. Conclusions.

The method of quasi-synchronous observations was useful, and therefore it was desired to continue works under the INTEROBS Program. Certain changes and additions, however, can be proposed for improving further operations. For example, it is far better if, instead of monthly observations sessions, we set up more prolonged observation periods. It would be better if the satellite were observed during the entire period when it is visible; however this is difficult to organize. Further, it is necessary in the future to simultaneously observe objects at various altitudes (on the same night), which makes it possible to determine the dependence of unexpected changes in atmospheric density on altitude.

It is useful to conduct, simultaneously with INTEROBS observations, photometric observations of the same objects (the SPIN Program). This makes it possible to investigate the agreement between changes in the period of rotation and the period of revolution of the same satellite.

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Finally, it would be useful to process the rich observation data obtained under the INTEROBS Program in order to calculate orbital elements used when processing the observations by quasi-synchronous methods. In this case the accuracy of the final results, mainly when determining temporary changes in atmospheric density, can be noticeably increased.

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INVESTIGATIONS BASED ON PHOTOMETRIC SATELLITE TRACKING

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Principal results of research based on the
SPIN Program are presented.

Photometric satellite tracking began as early as 1957, soon
after the launching of the first two Soviet satellites, first in the
USSR [1], [2] and then abroad [3]. Then theoretical works
devoted to the use and investigation of change in brightness of
satellites appeared (for example, [4, 5]), and at present much
literature has been devoted to this problem. Here we are dealing
with only one side of the problem — the investigation of the density
of the earth's atmosphere from photometric data on the deceleration
of rotation of oblong satellites relative to the centers of mass,
since the solution of just this problem makes up the international
SPIN cooperation program.

When studying the period of the change in brightness of the
boosters of the first Soviet satellites it was found that the
magnitude of the period does not remain constant [2, 3]. Attempts
were made to examine these changes as the result of a secular smooth
change in the period [6] and even, by means of artificial theoretical
constructions, to convert to observed nonuniform increase in period
into a linear increase [7]. Further investigations [8, 9] showed
that, obviously, the observed changes in the period of rotation of the

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satellite are associated with changes in the state of the earth's atmosphere and magnetic field.

The results of observations of the boosters of the third Soviet satellite are most convincing evidence in favor of this hypothesis. By the time this rocket was launched, the observers had already acquired vast experience in photometric tracking and, as a result, Soviet (mainly) and foreign observers had obtained, in the period June-November 1958, a vast amount of tracking data — about 20,000 moments of brightness maxima. The processing of some of these trackings [10] showed that the period of rotation of the satellite is undoubtedly affected by changes occurring in near-earth space in association with variations of solar activity.

Changes in the period of rotation of Satellite 1958 δ_1 about the center of mass showed a very close correlation with changes in solar activity. There was noted a considerable increase in deceleration of the satellite rotation immediately after strong chromospheric flares on the Sun and the geomagnetic disturbances that followed them; this increase was synchronous with an analogous change in the period of revolution of this satellite around the earth. At present, such a result is not unexpected.

In numerous articles, particularly in the series of very interesting works by Jacchia et al. [15], convincing proof is given of the connection between changes in the period of revolution of a satellite around the earth and the manifestations of solar activity. Since the rotation of a satellite about its center of mass is subject to the same laws of aerodynamics and electrodynamics as is revolution in orbit, it is natural that in the period of rotation there should be observed the same effects as in the period of revolution.

However, from the standpoint of investigating the connection of solar activity and phenomena in near-earth space, study of the period of rotation of a satellite about its center of mass has definite advantages over study of the orbital period. The fact of the matter is that the kinetic energy of the satellite is much lower than the energy of orbital revolution. Consequently, in certain cases in the

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period of rotation there may be observed small disturbances, although in the period of revolution these are not noted. An example of this nature is given in [10].

The general trend of the curve "period of revolution-date" for the booster of the third Soviet satellite is similar to the curves characterizing solar activity [11].

Experimental study of the connection found between the period of rotation and the changes occurring on the Sun has been carried out in more or less detail. However, if we are speaking about correlations of changes in period of rotation with various factors characterizing solar activity in the state of the earth's atmosphere and magnetic field, there is no uniqueness in such a correlation. In certain time intervals the correlation is best expressed with certain factors, in other time intervals — with other factors. Therefore at the present time, at the Kishinev Satellite Tracking Station, study has been undertaken to select 2-3 factors which might be sufficient to completely explain all features of the "period of rotation-date" curve. The basis for such work is the fact that changes in solar activity might be expressed in the period of rotation of the satellite basically (or only) through changes in the state of the earth's atmosphere and magnetic field. In [12], with stipulation of a number of assumptions, a formula has been obtained for determining atmospheric density ρ with respect to deceleration of the rotation of a cylindrical satellite

$$\rho = \frac{3\pi m (3D^2 + 2L^2)}{32 V_0 D L^3 (t_b - t_a)} \, \ln \frac{P_b}{P_a} \, ;$$

where m, D and L are the mass, diameter, and length of a cylindrical satellite, V_0 is its orbital velocity, and P_a and P_b are the periods of rotation at times t_a and t_b. This formula is applicable in any time interval $(t_b - t_a)$, assured by a sufficient number of observations. Thus it was possible to investigate short-period changes in density as well. The formula can be used for processing data on the period of rotation obtained by any method. However, for passive satellites such as boosters, there are no data on the period of rotation relative to the center of mass except for those obtained

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from photometry. From this standpoint, the photometry of boosters, making it possible to increase the "coefficient of usefulness" of the booster, in conjunction with appropriate theoretical investigations is undoubtedly worthy of attention.

It was also possible to obtain an equation for determining the deceleration of rotation of a satellite by the earth's magnetic field [16]. Consideration of deceleration caused by the appearance in the satellite of eddy currents made it possible to obtain more precise values of atmospheric density. The relation between magnetic and aerodynamic deceleration of satellite rotation was within the limits predicted by theory.

It should be pointed out that just as the results of [12] and [16] are applicable to any data on the period of rotation, so can the many results of operations conducted during the theoretical study of the rotation of satellites from the point of view of their orientation, rotation stability, stabilization, etc. (see, for example, [13, 14]) be applied to the period of rotation obtained from photometric data. During further operation it was of particularly great interest to investigate the period of rotation of a satellite in order to study those effects which Jacchia obtained for the period of revolution — the diurnal effect, the annual effect, and others.

It was proposed to perform such operations on the observations of the booster of the third Soviet satellite at the Kishinev Satellite Tracking Station. We should point out however that photometric observations of the booster of the third satellite with respect to quantity, time, and sometimes even quality, do not satisfy all requirements necessary for investigating certain precise effects.

From this point of view, great hope is placed on the international cooperative effort on the photometric tracking of satellites under the SPIN Program, which is carried out within the frameworks of the Commission on Multilateral Cooperation of the Academies of Sciences of the socialist countries on the problem "Scientific Investigations Using Satellite Tracking."

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During the seminar under the SPIN program,
Kishinev, 1967. In the middle — program
coordinator V. M. Grigorevskiy.

In August and September 1966, simultaneously with observations
under the INTEROBS Pro~ram, we conducted the first two sessions of
photometric tracking of satellites 1965-11-4 and 1965-53-6. Although
these sessions were merely test programs, the Soviet and foreign
stations obtained quite a vast amount of observational data (about
4000 moments of brightness maxima). The initial processing of these
observations has already been completed and the data have been
prepared for printing. Thus, in the near future the participants
and all those interested in the problem will obtain very interesting
experimental data. A detailed analysis of the investigated effects
is a matter for the future; however, we can state at this point that
even two brief series of observations have made it possible to note
interesting features in the change of the period of rotation of a
satellite: an increase in the period due to a strong solar flare,
and a quite remarkable coincidence between the curve of a change
in period and the curve of the change in solar radio radiation in the
decimeter band (this latter effect was first noted [10] for Satellite
1958 δ_1).

We should note, however, that a rapid change in the period of
rotation of a satellite (immediately following a rapid change in the
level of solar activity) results in the fact that it is difficult to
isolate small changes in the rotation period connected with small
variations in solar activity. In this regard it is particularly

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stressing that two very strong geomagnetic disturbances at the very end of August and the beginning of September 1966 occurred immediately in the interval between the two observation sessions under the INTEROBS as well as the SPIN Program.

The advantage of observation of a few satellites in all periods of their visibility over observations of many satellites during short INTEROBS and SPIN sessions is quite obvious. It is particularly important to assure such continuity in 1967-1969, during the period of maximum solar activity.

To investigate seasonal (annual) effects it would also be very desirable to extend the observations under the SPIN Program (as well as, it might be added, under the INTEROBS Program) to the winter season. From this point of view the desire expressed by the Helwăn Observatory (United Arab Republic) to participate in the SPIN operations is very promising, since weather conditions in the UAR make it possible to conduct observations practically the year round.

In the coming years, the following results should be sought under the SPIN Program:

a) To obtain good observational material: a large number of continuous observations of two-three satellites at different altitudes. It is extremely desirable that the objects and the observation intervals be the same as under the INTEROBS Program;

b) To theoretically investigate the deceleration of satellite rotation under the influence of electromagnetic, aerodynamic, and other factors under various conditions, in particular, with changes in the actual influencing factors and with changes in the satellite orientation;

c) To investigate statistically the changes in the rotation period in connection with changes in solar activity and seasonal changes in the earth's atmosphere.

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FACTS AND FIGURES

The Soviet Union

In 1957 the Astronomy Council of the Academy of Sciences of the USSR [AC AS USSR] set up a network of optical satellite tracking stations in the USSR. Sixty-six stations began operation at astronomical observatories, universities, and teachers' colleges located throughout the Soviet Union.

The methodology and scientific leadership of the Soviet network of optical satellite tracking stations was performed by the Sector on Optical Satellite Tracking of the AC AS USSR, organized in 1957. The Sector was headed by Deputy Chairman of the AC, A. G. Masevich.

In 1959 there was organized, at the AC AS USSR, the Zvenigorod experimental station which had the job of investigating new designs of equipment for satellite tracking, new observation methods, and also experimental observations of space objects. The leader of the Zvenigorod experimental station was A. M. Lozinskiy.
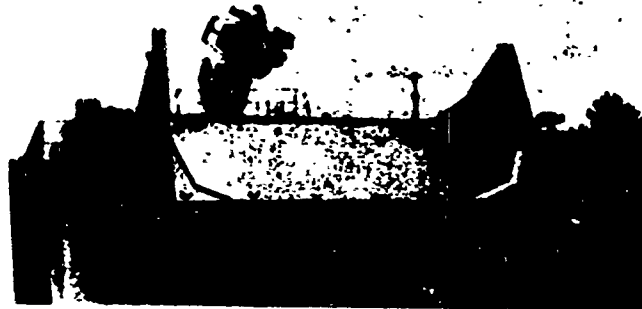
Set-up of special large satellite
camera at the Zvenigorod experimental
station of the AC AS USSR.

The Zvenigorod experimental station in 1963 conducted
experimental photographic observations of flashes from a pulsed
light source aboard an aircraft. Photography using the NAFA-3s-25
and NAFA MK-75 cameras showed the possibility of observing pulsed
light sources using satellite cameras.

In 1967 the Zvenigorod experimental station began study
of the AFU-75 camera designed for tracking weak satellites.

The AFU-75 cameras were also installed at stations in Riga,
Uzhgorod, Pulkovo.

Installation was begun at the Zvenigorod experimental station
in 1967 of a special large satellite camera (d = 550 mm, f = 700 mm).

In 10 years the Soviet Optical Satellite Tracking Stations
have conducted 5260 observations during 1240 passes of artificial
space objects. About 400 objects have been observed.

At Station No. 1031. On the left —
station leader A. A. Logvinenko.

In 10 years the stations from cooperating countries have sent
to the AC AS USSR and the "Kosmos" computer center 5180 observations
during 120,000 passes. About 700 space objects have been observed.

The most number of passes have been observed by the
following stations:

Station	Number of observed passes
No. 1042 Ryazan'	9300
No. 1078 Yeniseysk (opened in 1961)	8000
No. 1043 Samarkand	7100
No. 1062 Chernovtsy	5900
No. 1004 Arkhangel'sk	5100
No. 1051 Tartu	4800
No. 1044 Saratov	4300
No. 1014 Vologda	4200
No. 1018 Yerevan	3900
No. 1010 Blagoveshchensk	3700

The best results in INTEROBS observations have been achieved
by the following stations:

Station	Number of observed passes	Average number of observations during one pass
No. 1042 Ryazan'	441	30.2
No. 1062 Chernovtsy	322	6.3
No. 1024 Kishinev	236	9.6
No. 1023 Kiev	231	10.2
No. 1041 Rostov na Donu	233	9.4
No. 1018 Yerevan	150	14.7
No. 1017 Dnepropetrovsk	146	15.3

The most observations were made by the following individuals:

B. Ye. Tumyanyan, leader of Station No. 1018, Yerevan (since 1957) — about 16,000.

O. G. Bogdanov, worker at Station No. 1042, Ryazan' (since 1961) — more than 11,000.

P. M. Pershin, Deputy Director of Station No. 1078, Yeniseysk (since 1961) — about 9,000.

V. A. Vorotnikov, leader of Station No. 1078, Yeniseysk (since 1961) — more than 8,000.

V. I. Kuryshev, leader of Station No. 1042, Ryazan' (since 1957) — more than 8,000.

A. D. Chirtsov, leader of Station No. 1004, Arkhangel'sk (since 1957) — about 8,000.

E. Vares, observer at Station No. 1051, Tartu (since 1959) — more than 7,000.

The most photographs of satellite passes during synchronous observations of artificial satellites have been obtained by the following stations:

Station	Number of obtained photographs
No. 1075 Tashkent	1989
No. 1077 Nikolayev	1343
No. 1074 Ashkhabad	1039
No. 1072 Zvenigorod	904
No. 1901 Cairo (Soviet-Egyptian Station)	819
No. 1084 Riga	633
No. 1063 Dushanbe	609
No. 1079 Irkutsk	589

Space probes Mars-1, Luna-4, Luna-7, Luna-11, Luna-12 and Luna-13 have been observed at the Crimean Astrophysical Observatory AS USSR, using a 260-cm reflector and a 50-cm meniscus telescope, equipped with a television apparatus or an electron-optical converter.

Photographs of the space probes Luna-7, Luna-8, Luna-9, Luna-10, Luna-11, Luna-12 and Luna-13 were obtained by observers at the

Abastumani Astrophysical Observatory of the AS of the Georgian SSR
using a 700-mm meniscus telescope.

More than 300 scientific articles on the subject of
satellite tracking, tracking data processing, and the use of
tracking results for scientific research have been published by
workers at the Optical Satellite Tracking Stations in the
"Bulletin of the Optical Satellite Tracking Stations,"
"Astronomical Journal," "Astronomical Circular," "Works" of
observatories and universities, and other publications.

Dissertations on subjects connected with optical satellite
tracking were defended by the following individuals:

1. M. K. Abele
2. V. M. Grigorevskiy
3. A. A. Logvinenko
4. V. A. Merkushev
5. A. S. Sochilina
6. V. A. Yurevich

Dissertations were prepared by the following:

A. G. Krylov
K. K. Lapushka
M. K. Liygant
S. K. Tatevyan

Scie.tific workers of the Geodetic Service of the USSR,
B. M. Klinitskiy and G. A. Ustinov performed theoretical research
in the field of geodetic processing of satellite tracking results
and methods of setting up networks for space triangulation.

The AC AS USSR, in order to coordinate operation of the stations
for visual and photographic satellite tracking in the USSR, set up
meetings with the station directors. In 1957-67 there were 6 All-Union
Meetings and 5 Regional Meetings.

The meetings of participants under the INTEROBS Program were held in Moscow (1966) and in Ryazan' (1967).

In the summer of 1957 the AC AS USSR organized in Ashkhabad the first courses for satellite observers. The participants in the courses later headed up operation of optical satellite tracking stations.

Meeting of leaders of Soviet Optical Satellite Tracking Stations. Moscow, 1961.

A summer school on photographic satellite tracking was held in Tashkent in September 1965. In addition to Soviet observers, the school was attended by representatives of scientific institutions in Bulgaria, Hungary, East Germany, Mongolia, Poland, Rumania, and Czechoslovakia. The students listened to 14 lectures on methods of photographic satellite tracking, methods of processing these tracking data, and ways of using the obtained results for solving scientific problems. The participants improved their practical skills by participating in observations, processing of negatives, the reception of radio time signals, and the calculation of ephemerides.

A seminar on the "Method of Calculating Ephemerides for Satellite Tracking" was held in May 1967 at Yeniseysk. The participants of the seminar studied methods of conducting an ephemeris service under

satellite-tracking-station conditions, and familiarized themselves
with work in this field conducted by the station at Yeniseysk.

A second summer school on photographic satellite tracking
was held in October 1967 at the Main Astronomical Observatory
of the AS USSR at Pulkovo. The basic task of the school was
to teach methods of photographic satellite tracking for
geodetic purposes.

A number of new instruments and devices for tracking space objects
have been designed at optical satellite tracking stations.
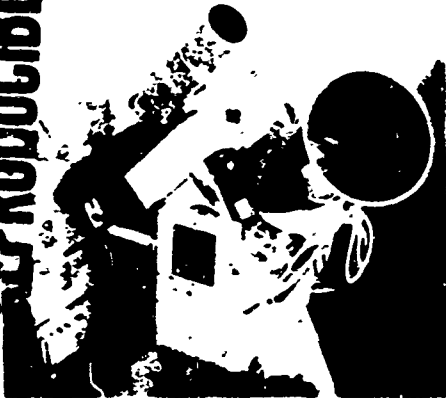
The AFU-75 camera. Station
No. 1084, Riga (USSR).

Station No. 1084, Riga. An
experimental model of the AFU-75 4-axis
automatic camera for photographing the
observations of satellites has been
designed and prepared. The designers
are M. K. Abele and K. K. Lapushka.

Station No. 1039, Main Astronomical
Observatory AS USSR, Pulkovo. A camera
with moving film has been designed and
manufactured for photographing the passes
of weak artificial satellites. The
designer is L. A. Panayotov.

Station No. 1031, L'vov. There has been designed and set up
an automatic time service that operates according to a set program.
There have been developed, among others, devices for automatic camera
control. The designer is A. A. Logvinenko.
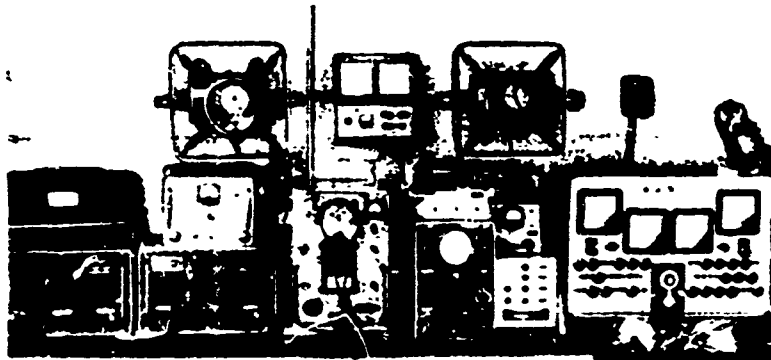
The time service of
Station No. 1031,
L'vov (USSR).

Station No. 1067, Alma-Ata. There has been designed and set up an instrument for photographic satellite tracking. The designers are N. D. Kalinenkov and K. F. Cherepanov.

The Crimean Astrophysical Observatory of the AS USSR. Systems have been set up for optical tracking of remote space objects: a 50-cm meniscus telescope with a television attachment, and a 260-cm reflector with an electron-optical converter or a television appartus.

VETERANS OF OPTICAL SATELLITE TRACKING

Abele, Maris ˈarlovich. Worker at photograghic tracking Station No. 1084, Riga. Designer of the AFU-75 camera.

Agzamov, Abzal Agzamovich. Director of Station No. 1052, Tashkent. Excellent observer.

Alaniya, Ivan Filippovich. Scientific worker at the Abastumani Astrophysical Observatory of the AS Georgian SSR.

Artemkin, Yevgeniy Yevdokimovich. Deputy Director of Station No. 1042, Ryazan'.

Barkhatova, Klavdiya Aleksandrovna. Organizer and first director of Station No. 1045, Sverdlovsk. Presently director of the Astronomical Observatory of Sverdlovsk University.

Belenko, Vladimir Ivanovich. Scientific worker of the Zvenigorod Experimental Station of the AC AS USSR

Benyukh, Aleksandr Sergeyevich. Mechanic, participant in all structural operations at Station 1023, Kiev.

Bratiychuk, Matrena Vasil'yevna. Organizer and director of Station No. 1055, Uzhgorod. She had published 6 articles on questions involving satellite tracking.

Bukhantsev, Lev Terent'evich. Organizer and director of Station No. 1010, Blagoveshchensk na Amure. The first one in the Soviet Union to observe weak satellites.

Batrakov, Yuriy Vasil'evich. Scientific worker at the Institute of Theoretical Astronomy of the AS USSR.

Vaysov, Marat Akhmatovich. Director of Station No. 1020, Kazan'.

Vidyakin, Vladimir Vasil'yevich. Deputy Director of Station No. 1004, Arkhangel'sk.

Vorob'yeva, Valentina Alekseyevna. Worker at Station No. 1024, Kishinev.

V'yushkov, Pavel Vasil'evich. Organizer and director of Station No. 1044, Saratov. His station has always been one to provide some of the best observations.

Galstyan, Frunzik Nersesovich. Observer at Station No. 1018, Yerevan.

Grigorevskiy, Vitaliy Mikhaylovich. Director of Station No. 1024, Kishinev. One of the initiators of photometric observations of artificial satellites, and coordinator of the international SPIN scientific program. He has published more than 20 articles on questions associated with photometric satellite tracking.

Guseynov, Ragim Eyub ogly. Worker at Station No. 1007, Baku. Before 1960 he was the station leader.

Danilenko, Ivan Vasil'yevich (deceased). Organizer of Station No. 1025, Komsomol'sk na Amure.

Demidovich, Yevgeniy Georgiyevich. Organizer and Deputy Director of Station No. 1050, Gor'kiy.

Dobronravin, Petr Pavlovich. Scientific worker at the Crimean Astrophysical Observatory AS USSR.

Doman, Viktor Gerasimovich. Deputy Director of Station No. 1037, Omsk.

Durinov, Ivan Alekseyevich. Organizer and director of Station No. 1056, Ulan-Ude.

Yeranskaya, Liliya Nikolayevna. Deputy Director of Station No. 1056, Ulan-Ude.

Yerpylev, Nikolay Petrovich. Science worker of the AC AS USSR. Director of the "Satellite Geodesy" group of the AC.

Zhongolovich, Ivan Danilovich. Deputy Director of the Institute of Theoretical Astronomy of the AS USSR. Conducted a number of investigations in the geodetic and geophysical application of the results of satellite tracking.

Ivanov, Vladimir Nikolayevich. Director of Station No. 1027, Krasnodar.

Ivanov, Aleksandr Fedorovich. Director of Station No. 1029, Kurgan. Excellent observer.

Izhakevich, Yelena Mikhaylovna. Deputy Director of Station No. 1023, Kiev.

Isayev, Agaguseyn Mamedrza ogly. Worker at Station No. 1007, Baku.

Kadyrov, Mennan Khalimovich. Organizer and director of Station No. 1006, Ashkhabad.

Kan, Konstantin Nikolayevich. Organizer and director of Station 1065, Sakhalinsk.

Kasimenko, Tat'yana Vladimirovna. Scientific worker of the AC AS USSR. Coordinator of the INTEROBS Program in the USSR.

Kakhusk, Reyn Petrovich. Deputy Director of Station No. 1051, Tartu.

Kvirkveliya, Georgiy Doment'yevich. Organizer and director of Station No. 1053, Tbilisi.

Kevanishvili, Galaktion Fiofilovich. Deputy Director of Station No. 1053, Tbilisi.

Kereselidze, Avtandil Markozovich. Worker at Station No. 1053, Tbilisi.

Kovalenko, Nina Nikolayevna. Scientific worker of the AC AS USSR. Coordinator of the sessions on synchronous photographic tracking.

Kolchin, Anatoliy Alekseyevich. Director of Station No. 1048, Volgograd.

Kondratenko, Vladimir Maksimovich. Organizer of Station No. 1062, Chernovtsy. At the present time he is the science director of the station.

Kondratenko, Maksim Maksimovich. Director of the observation group of Station No. 1052, Chernovtsy.

Kuryshev, Vasiliy Ivanovich. Organizer and director of Station No. 1042, Ryazan'. Excellent observer. Published 16 works on subjects connected with optical satellite tracking.

Lavrov, Mikhail Ivanovich. Organizer and director of Station No. 1076, Astronomy Observatory im. Engel'gardt.

Lagovskiy, Vladimir Sergeyevich. Chief observer and photographer of Station No. 1014, Vologda.

Lapushka, Kazimir Kazimirovich. Director of the photographic tracking Station No. 1084, Riga. Designer of the AFU-75 camera.

Leykin, Grigoriy Aleksandrovich. Scientific worker of the AC AS USSR. One of the organizers of the Soviet network of optical satellite tracking stations.

Leshakov, Semen Alekseyevich. Organizer and director of Station No. 1038, Petrozavodsk.

Liygant, Myart Karlovich. Director of Station No. 1051, Tartu.

Litvinenko, Taisiya Mikhaylovna. Deputy director of Station No. 1063, Orenburg.

Logvinenko, Aleksandr Alekseyevich. Director of Station No. 1031, L'vov. He has done much work toward modernizing the station equipment, and on creating new methods for time recording. Published about 30 articles of questions of satellite tracking.

Lozinskiy, Aleksandr Markovich. Organizer and director of the Zvenigorod Experimental Station of the AC AS USSR. Director of first courses for satellite observers.

Lur'ye, Mariya Aleksandrovna. Scientific worker of the AC AS USSR. Coordinator of the Soviet network of visual satellite tracking stations.

Makarova, Yelizaveta Nikolayevna. Scientific worker of the Institute of Theoretical Astronomy of the AS USSR.

Makover, Samuil Grigor'yevich. Scientific worker of the Institute of Theoretical Astronomy of the AS USSR.

Mozhzherin, Veniamin Mikhaylovich. Scientific worker of the Crimean Astrophysical Observatory of the AS USSR.

Moskaleva, Galina Vasil'yevna. Deputy director of Station No. 1055, Uzhgorod.

Nepogod'yev, Vasiliy Gennadiyevich. Organizer, director and excellent observer at Station No. 1014, Vologda.

Nizamov, Babreddin Imadovich. Organizer and director of Station No. 1011, Bukhara.

Osipov, Aleksandr Kuz'mich. Organizer and director of Station No. 1023, Kiev.

Pavlenko, Petr Petrovich. Worker at Station No. 1060, Khar'kov.

Pavlyniv, Yevgeniy Aleksandrovich. Director of Station No. 1062, Chernovtsy. He has devoted much attention toward improving observation methods.

Panova, Galina Valentinovna. Worker at Station No. 1039, Pulkovo.

Parshin, Serafim Nikolayevich. Organizer and director of Station No. 1050, Gor,kiy.

Pluzhnikov, Vitaliy Kharitonovich. Director of Station No. 1060, Khar'kov. His station assures high quality observations.

Poletayev, Aleksey Pavlovich. Organizer of Station No. 1014, Vologda. Since he is presently the prorector of Vologda Teachers' Institute, he plays a great role in the work of the station.

Ponomarev, Yuriy Iosifovich. Organizer and director of Station No. 1063, Orenburg.

Popov, Pavel Ivanovich. Organizer and director of Station No. 1049, Syktyvkar.

Pyshnenko, Mikhail Nikolayevich. Deputy director of Station No. 1059, Khabarovsk.

Rozhkovskiy, Dmitriy Aleksandrovich. Organizer and first director of photographic tracking Station No. 1067, Alma-Ata. Deputy director of the Astrophysical Institute of the AS Kaz SSR.

Romanova, Galina Vladimirovna. Scientific worker at the Zvenigorod Experimental Station of the AC AS USSR.

Safronov, Yuriy Ivanovich. Deputy director of Station No. 1062, Chernovtsy.

Semenov, Ivan Semenovich. Organizer and director of Station No. 1058, Frunze.

Solov'yev, Viktor Yevgen'yevich. Scientific director of Station No. 1017, Dnepropetrovsk.

Slovokhotova, Nina Pavlovna. Scientific worker of the AC AS USSR. Secretary of the Commission on Multilateral Cooperation on the Problem "Scientific Research Using Observations of Artificial Satellites."

Sorokin, Vsevolod Aleksandrovich. Organizer and director of Station No. 1059, Khabarovsk.

Sochilina, Alla Semenovna. Scientific worker of the Institute of Theoretical Astronomy of the AS USSR.

Suleymanov, Vafa Sagomanovich. Director ·· Station No. 1057, Ufa.

Trofimtseva, Irina Semenovna. Worker of the AC AS USSR.

Tumanyan, Benik Yesayevich. Organizer and director of Station No. 1018, Yerevan. Excellent observer. Most number of observations among all the observers of the Soviet Union.

Filippov, Innokentiy Zakharovich. Organizer and director of Station No. 1064, Chita.

Pirago, Boris Alekseyevich. Director of photographic tracking Station No. 1039, Pulkovo. Compiler of program for synchronous photographic satellite tracking.

Khivrenko, Anatoliy Pavlovich. Deputy director of Station No. 1024, Kishinev.

Chebotarev, Gleb Aleksandrovich. Director of the Institute of Theoretical Astronomy of the AS USSR. Director of work in the field of studying the motion of artificial space objects.

Chikarenko, Aleksandr Leonidovich. Excellent observer from Station No. 1017, Dnepropetrovsk. After graduating from Dnepropetrovsk University he continued working at the station, and dire ing the observations.

Chirtsov, Anton Dmitriyevich. Organizer and director of Station No. 1004, Arkhangel'sk.

Shadiyev, Orif. Deputy director of Station No. 1011, Bukhara.

Shvalagin, Irina Vasil'yevna. Worker at Station No. 1055, Uzhgorod.

Shmeling, Valerian Vladimirovich. Organizer and director of Station No. 1040, Riga.

Shut'yeva, Raisa Mikhaylovna. Laboratory technician at Station No. 1060, Khar'kov.

Shchegolev, Dmitriy Yevgen'yevich. Director of Station No. 1039, Pulkovo. Initiator of synchronous photographic satellite tracking.

Yudkina, Valentina Petrovna. Organizer and director of Station No. 1041, Rostov na Donu.

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The Best Stations:

Station No. 1101, Sofia. Organized in 1957 at the Section of Astronomy of the Bulgarian Academy of Sciences in Sofia· since that time it has continuously participated in satellite tracking. The station conducts theoretical research in the field of the study of satellite orbits, the earth's gravitational field, and the behavior of the upper atmosphere. The station participates in the INTEROBS Program and in synchronous photographic satellite tracking.

Station No. 1102, Stara Zagora. Organized in 1961 at the "Yuriy Gagarin" National Observatory. The observers are workers of the observatory and senior scientists. The station participates in the INTEROBS Program, occupying one of the top positions with respect to quality and quantity of observations. The station is also actively involved in photometric observations under the SPIN Program.

Veterans of Optical Satellite Tracking:

Professor Nikola Bonev. Coordinator of Bulgarian stations and director of Station No. 1101, Sofia.

Bonyu Bonev. Director of Station No. 1102, Stara Zagora.

Vladimir Kraychev. Most active observer of Station No. 1101, Sofia.

Aleksandr Tomov. One of the first Bulgarian observers. He began working at Station No. 1101, Sofia; at the present time he is director of Station No. 1103, Belogradchik.

N. Bonev   A. Tomov   B. Bonev

Hungary

The Best Stations:

Station No. 1111, Budapest. Organized in 1957 at the Observatory of the Hungarian Academy of Sciences. The observers are observatory workers. The station participates in the INTEROBS Program, in observations and their processing.

Station No. 1113, Baja. Organized at the Astronomical Observatory in 1957. Since that time it has actively participated in satellite tracking under various programs: for the ephemeris service, for the INTEROBS Program, for space geodesy purposes, etc. The station conducts theoretical investigations within the frameworks of the INTEROBS Program.

Station No. 1112, Sombathely. Organized in 1957 at the Gotthard Observatory. The station participates in INTEROBS observations.

Veterans of Optical Satellite Tracking:

I. Almár. Coordinator of operations of Hungarian stations, director of Station No. 1111, Budapest. One of the initiators of the INTEROBS Program.

K. Tali. Active observer of Station No. 1111, Budapest.

A. Gesztesi. Active observer of Station No. 1111, Budapest.

E. Illés. Active observer of Station No. 1111, Budapest.

M. Ill. Director of Station No. 1113, Baja. One of the initiators and the coordinator of the INTEROBS Program.

K. Siutó. Observer of Station No. 1113, Baja. Participates in synchronous photographic satellite tracking.

G. Szabo. Director of Station No. 1114, Miskolc.

G. Tot. Director of Station No. 1112, Sombathely.

P. Varga. Observer of Station No. 1114, Miskolc.

A. Horváth. Observer of Station No. 1114, Miskolc.

I. Almár

GRAPHIC NOT REPRODUCIBLE

M. Ill

East Germany

The Best Stations:

Station No. 1120, Bautzen. Since 1958 has participated in satellite tracking. In 1961, together Hungarian stations, participated in first session of observations under the INTEROBS Program, and continues these operations at the present time.

Station No. 1184, Eulenburg. Organized in 1957 at the "Yuriy Gagarin" National Observatory. For 10 years has observed satellites for the ephemeris service.

Station No. 1185, Rodewisch. Organized in 1957 at the school observatory and since that time has taken an active part in satellite observations for the ephemeris service. In 1961, together with Hungarian stations, participated in the first session of observations under the INTEROBS Program and continues this work at present.

Veterans of Optical Satellite Tracking:
Professor Edgar Penzel. Director of Station No. 1185, Rodevish.

Edgar Otto. Director of Station No. 1184, Eulenburg.

Martel Otto. Observer of Station No. 1184, Eulenburg.

Kurt Arnold. Coordinator of observation and theoretical works under the Laplace azimuth program.

K.
Arnold

Gerhardt Felsmann. Former coordinator of German stations.

Karl Marek. Observer of the Potsdam Geodetic Institute.

GRAPHIC NOT REPRODUCIBLE

Poland

The Best Stations:

Station No. 1151, Olsztyn. Actively participates in satellite tracking under the INTEROBS Program and in processing these observations in order to study variations in atmospheric density. The station workers also participate actively in balancing and analyzing the accuracy of the space trilateration and triangulation networks.

Station No. 1155, Warsaw. Organized in 1957 under the Astronomical Observatory. At the present time participates actively in INTEROBS observations, also specializes in observations of weak satellites (up to 12 stellar magnitudes) to satisfy the needs of the ephemeris service.

Station No. 1154, Poznan. Since 1957 has conducted observations of satellites for the ephemeris service. Since 1963 has participated in synchronous photographic tracking for purposes of space geodesy.

Veterans of Optical Satellite Tracking:

Ludoslaw Cichowicz. Coordinator of Polish stations. Heads up theoretical investigations in the field of space triangulation. Director of the subcommission "Satellite Geodesy."

Maciej Bielicki. Director of Station No. 1155, Warsaw.

Wlodzimierz Baran. Director of Station No. 1151, Olsztyn. Conducts theoretical research under the INTEROBS Program.

Hieronim Gurnik. Director of Station No. 1154, Poznan.

Janusz Zielinski. One of the organizers of satellite tracking in Poland. Conducts research work in the field of space geodesy.

Kazimierz Latka. Participates in satellite tracking, and in the organization of observations and theoretical research.

Weneda Dobachewska. Participates in satellite tracking, and in the organization of observations and theoretical research.

Wojciech Pachelski. Participates in satellite tracking, and in the organization of observations and theoretical research.

L. Cichowicz

GRAPHIC NOT REPRODUCIBLE

H. Gurnik

GRAPHIC NOT REPRODUCIBLE

Rumania

The Best Stations:

Station No. 1131, Bucharest. Organized in 1957 under the Astronomical Observatory. Since this time has conducted satellite tracking for the ephemeris service. Participates in synchronous photographic tracking and in INTEROBS observations. Station workers conduct broad scientific research on the use of quasi-synchronous observations for space geodesy.

Station No. 1132, Cluj. Opened in 1957 under the Astronomical Observatory. One of the best stations, conducting satelli tracking for the ephermeris service. Participates in observations under the INTEROBS Program and in photometric observations under the SPIN Program. The station workers, besides making observations, conduct research to improve methods of processing INTEROBS observations.

Veterans of Optical Satellite Tracking:

Professor Calin Popovici. Coordinator of Rumanian station and director of Station No. 1131, Bucharest. Developed a method of processing quasi-synchronous observations of artificial satellites using coincidence circles.

Professor Gheorghe Kiss. Director of Station No. 1132, Cluj.

C. Popovici   G. Kiss

GRAPHIC NOT REPRODUCIBLE

The Best Station:

Station No. 1145, Prague. Organized in 1957 under the National Astronomical Observatory; actively participates in satellite tracking for space triangulation purposes.

Veterans of Optical Satellite Tracking:
Ladislav Sechnal. Coordinator of Czechoslovakian stations. Conducts vast scientific research work in the field of satellite orbit study.

Alois Vratník. Director of Station No. 1145, Prague. Active observer.

Milan Antale. Director of Station No. 1142, Skalnato Pleso.

Ladislav Sechnal together with G. A. Chebotarev (USSR) and with W. Cichowicz (Poland).

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International Meetings of Satellite Observers

The first international meeting of satellite observers was
held in January 1961 in the USSR.

About 20 representatives of Bulgaria, Hungary, East Germany,
China, Mongolia, Poland, the Soviet Union, and Czechoslovakia met at
the House of Friendship of Nations on Kalinin Prospect in Moscow.
During the meetings and in individual sessions they familiarized one
another with their works and discussed what themes to select for
scientific cooperation between the Academies of Sciences of the
socialist countries.

The second meeting on questions of satellite tracking
(November 1962, Leningrad, USSR) was devoted to photographic
observation methods (instruments, photographing methods, methods
of processing the obtained results).

The third meeting of satellite observers of the socialist
countries took place in Moscow in December 1963. The participants
of the conference discussed mainly questions involving synchronous
photographic observations of satellites and balloons, and basic
visual observations of low-flying satellites.

More than 70 persons from 10 countries participated in the
Riga Conference (February 1965, USSR). Forty-two reports were
read at 8 sessions. At the conference there were discussed
various methods of satellite tracking and possible methods of

processing the obtained data; the results obtained by the cooperating countries in 1964 were also analyzed.

In accordance with recommendations of the Commission on Problems, the Fifth International Session of Satellite Observers met in October 1955 in Budapest (Hungary). Particular interest among the participants of the conference was evoked by the report of Professor I. D. Zhongolovich, in which he presented a new method for processing basic visual observations of low-flying satellites. This method, which makes it possible to determine the period of satellites with increased accuracy, was accepted as being most useful and expedient, and at present is widely used for processing INTEROBS observations.

The Sixth Scientific Meeting of Satellite Observers met October 1966 in Potsdam (East Germany). The makeup of the conference participants (123 delegates from 14 countries) reflected the increasing interest of scientists of various countries in the work conducted along the lines of multilateral cooperation of the problem "scientific research using satellite tracking." Discussion of the results obtained followed, as was usual, two directions: investigation of the upper atmosphere on the basis of satellite orbit analysis, and the use of satellite observations for purposes of geodesy.

Participants of the conference of the Commission on Multilateral Cooperation examine the AFU-75 camera. Uzhgorod, 1967.

In May 1967, in Uzhgorod, there met a special conference of the Commission on Problems "scientific research using satellite tracking," devoted to the photometry of satellites. Two programs were discussed: the SPIN Program, providing for photometric study of satellite rotation for studying variations in atmospheric density in connection with changes in solar activity, and the program for photometric observations of satellites as they pass into the earth's umbra, for study of the optical properties of the upper atmosphere.

In September 1967, in Zakopane (Poland), there convened the Seventh Scientific Conference on Questions of Satellite Tracking, and the regular meeting of the Commission on Problems.

The conference discussed reports on all subjects of cooperation. As a result of the discussion it appeared that the structure of the Commission on Problems requires improvement for more active coordination of the operations. A decision was made to form two sub-commissions: "Satellite Geodesy" and INTEROBS.

USSR. Station No.
1007, Baku.
NAFA-3s-25 camera.

USSR. Station No. 1039, Pulkovo. Station
pavilions.

USSR. Station No. 1039, Pulkovo.
First photograph of an artificial
satellite obtained in the USSR;
trail of the booster of the first
Soviet artificial earth satellite.
October 10, 1957; AKD astrograph.
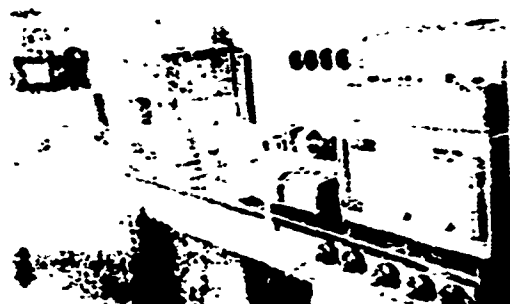
USSR. Station No. 1007,
Baku. The station time ser-
vice.

USSR. Station No. 1050,
Gor'kiy. Deputy director
of the station Ye. G.
Demidovich plots the satellites
route on a globe of the world.

USSR. Station No.
1004, Arkhangel'sk.
Preparation for obser-
vations.

USSR. Station No. 1052, Tashkent. Station director A. A. Agzamov decodes ephemeris telegrams.

USSR. Station No. 1004, Arkhangel'sk. Station director A. D. Chirtsov (in the middle) directs the set up of the telescopes before the observations.

USSR. Station No. 1045, Sverdlovsk. Two-story pavilion for observations. The recording apparatus is located in the first story of the building.

USSR. Station No. 1031, L'vov. Observations on the KFT 10/20 cinephototheodolite.

USSR. Station No. 1063, Orenburg. Processing of observations. In the middle — station director U. N. Ponomarev.

GRAPHIC NOT REPRODUCIBLE

USSR. Station No. 1055, Uzhgorod. Station director M. V. Bratiychuk (second from the right) with his observers.
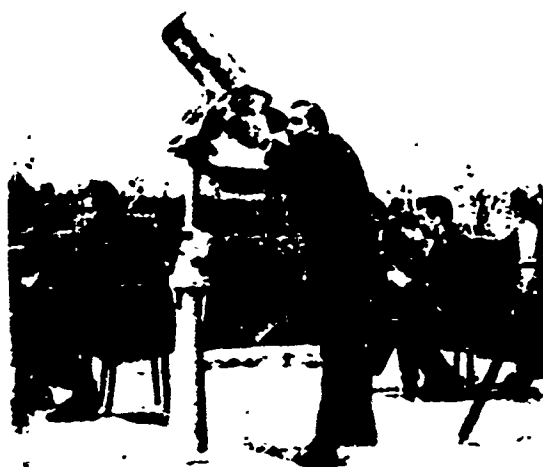
USSR. Station No. 1018, Yerevan. During the observations. In the middle — station director B. Ye. Tumanyan.

USSR. Station No. 1059, Khabarovsk. AT-1 telescope, mounted on a theodolite.

USSR. Station No. 1018, Yerevan. Measurement of a negative on the UIM-21 coordinate measuring apparatus.

USSR. Station No. 1044, Saratov. Station director P. V. T'yushkov (on the left) helps the observer set up the TZK binocular.
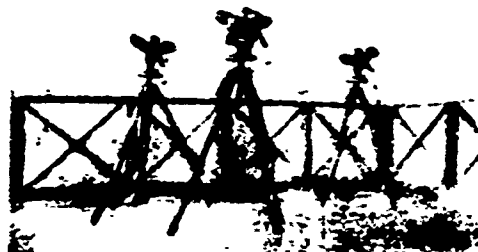
USSR. Station No. 1044, Saratov. TZK binoculars on the observation platform.

USSR. Crimean
Astrophysical
Observatory.
Preparation for
the observation
of remote space
objects on the
50-cm meniscus
telescope.

USSR. Station No. 1051,
Tartu. Station director
M. K. Liygant.

USSR. Station No.
1038, Petrozavodsk.
Station director
S. A. Leshakov (on
the right) and
observers at the
satellite observa-
tion point.

USSR. Station No. 1080,
Nal'chik. Observations
of the second Soviet
artificial earth
satellite, 1959.

USSR. Station No. 1075,
Tashkent. Preparation
for photographic obser-
vations. On the left —
director of the
Astronomical Institute,
Academician of the AS
Uzb SSR V. P. Shcheglov.

USSR. Station No. 1003,
Abastumani. Photograph of
the automatic station Luna-
10 and its booster on March
31, 1966 (70-cm meniscus
telescope).

USSR. Station No. 1014, Vologda.
Photograph of the trail of the
second Soviet artificial satellite
above Vologda. ("Leningrad" camera.
1958).

USSR. Station No. 1014,
Vologda. Station worker
V. S. Lagovskiy photographs
a satellite with a hand
camera.

**GRAPHIC NOT
REPRODUCIBLE**

USSR. Station No. 1014, Vologda. During
the observations. 1957.

Poland. Station No. 1154,
Poznan. Camera for satellite
photography.

Poland. Station No. 1160,
Juzefosław. At the telescope for
artificial satellite observations.

Poland. Station No. 1151,
Olsztyn. Preparation for
satellite observations.

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REPRODUCIBLE
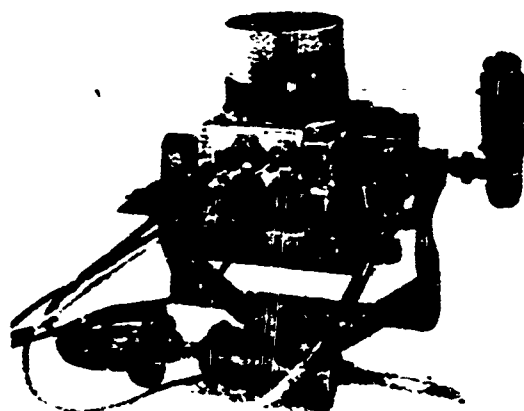
Poland. Station No. 1160,
Juzefosław. Kodak camera.
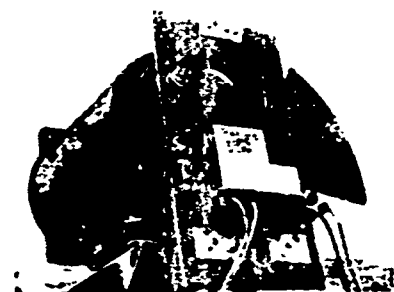
Czechoslovakia. Station
No. 1143, Brno. A camera
used for artificial
satellite tracking.

Poland. Station No. 1155, Warsaw.
Time service. On the right —
station director M. Belicki.

Rumania. Station No. 1132, Cluj. On the observation platform.

Czechoslovakia. Station No. 1145, Prague. Station director, Vratnik.

Cuba. Station No. 1752, Cacaual. Group of observers.

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Cuba. Station No. 1752, Cacaual. Preparation for the observations.

Czechoslovakia. Station No. 1142, Skalnato Pleso. Preparation for the observations. On the right — station direction M. Antal.

East Germany. Station No. 1120, Bautzen. Satellite observations. On the left — station leader H. Nitschman.

Bulgaria. Station No. 1101,
Sofia. A. M. Lozinskiy (USSR)
and station worker L. A.
Sadovski at the cinetheodolite.
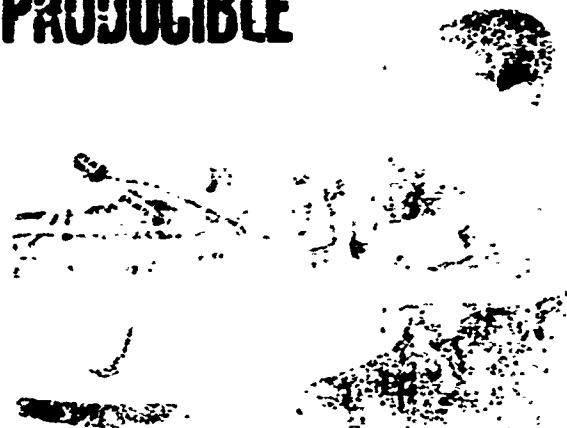
Mongolia. Station No. 1660,
Ulan-Bator. Station director
Radnaa at the coordinate
measurement instrument.

Bulgaria. Station No. 1102,
Stara Zagora. Pavilion for
photographic satellite tracking.
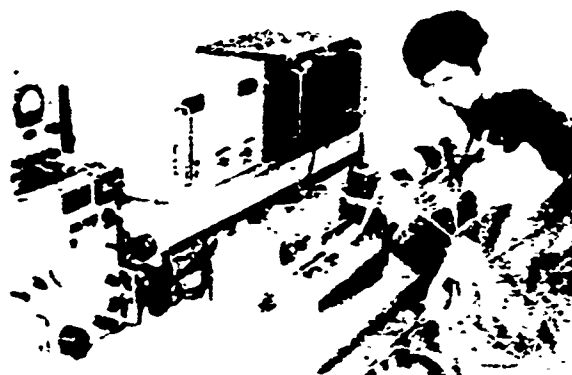
Mongolia. Station No. 1660,
Ulan-Bator. The equipment of the
station for satellite tracking.
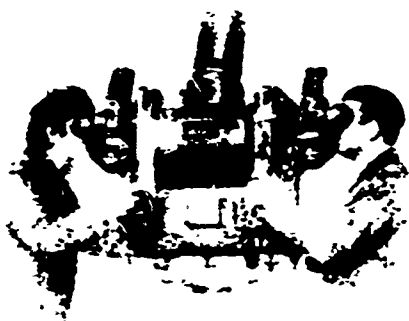
Bulgaria. Station No. 1102,
Stara Zagora. Observations
using the cinetheodolite.
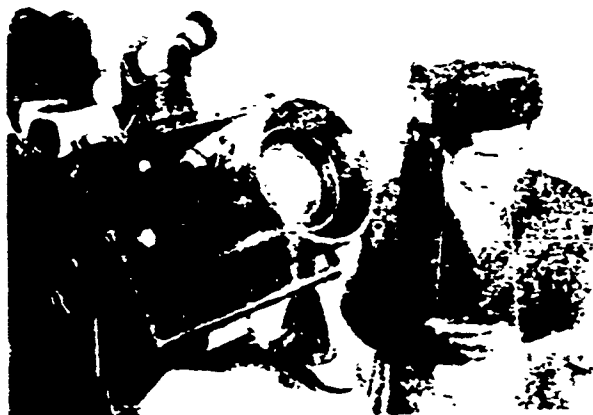
Mongolia. Station No. 1660, Ulan-
Bator. Preparation for photo-
graphic observations of satellites
using the NAFA-3s-25 camera.

Poland. Station No. 1155, Warsaw.
Observation platform.
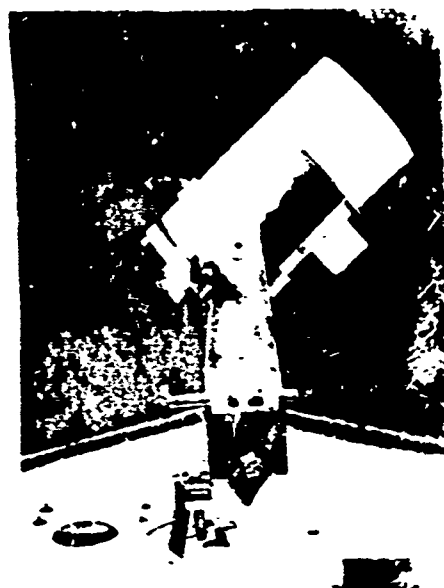
Poland. Station No. 1156,
Boruwecz. Photographic
camera with Sonnar
objective.
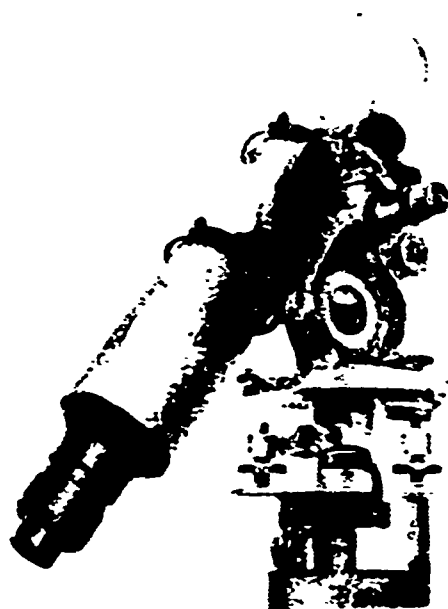
East Germany. Station No. 1120,
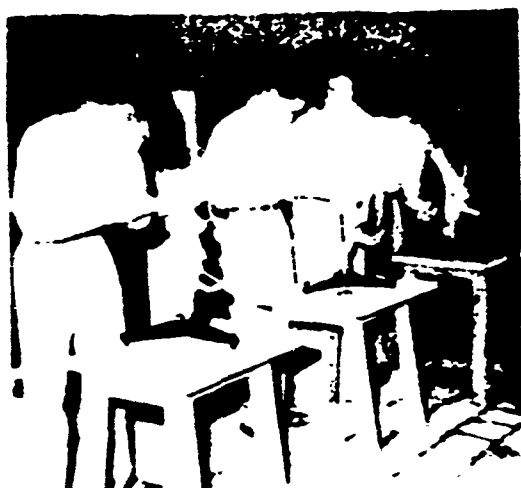Bautzen. Theodclite with Zeiss
objective.

East Germany. Station No.
1180, Schwerin. Station
director H. Mras.

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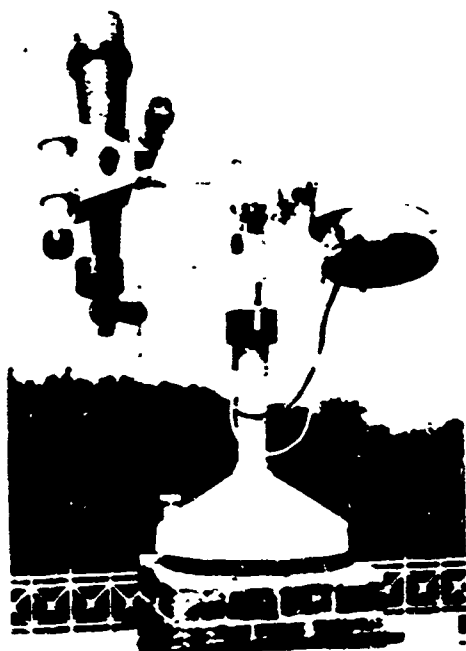
East Germany. Station No.
1181, Potsdam. Camera for
photographing artificial
earth satellites, pre-
pared at the Potsdam
Geodetic Institute.
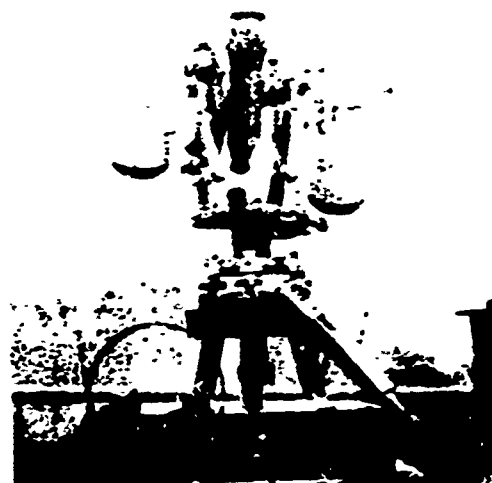
East Germany. Station No.
1180, Schwerin. Installation.
of the satellite tracking.

Vietnam. Station No. 1581,
Hanoi. During the observa-
tions.

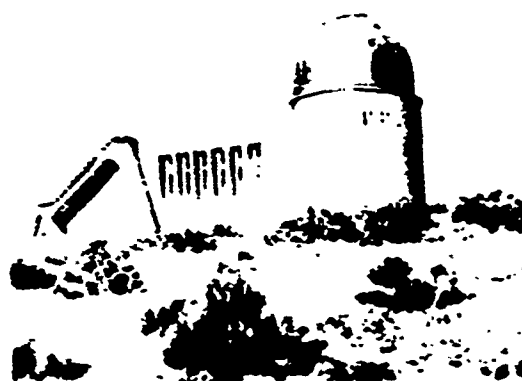Hungary. Station No.
1114, Miskolc. Station
director G. Szabo.

GRAPHIC NOT REPRODUCIBLE
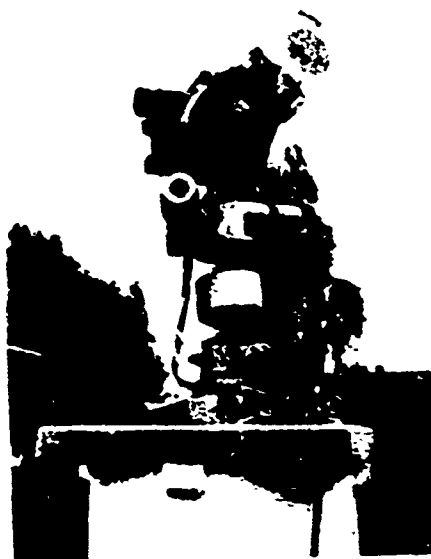
The Netherlands. Station
No. 4119, Oost Souburg.
K-24 camera used for
satellite tracking.

Bulgaria. Station No. 1103,
Belogradchik. Observation site
on the observatory roof.

East Germany. Station No.
1184, Eulenburg. Station
director E. Otto and station
worker M. Otto.

The Netherlands. Station
No. 4119, Oost Souburg.
Station director T.
Vermeesch.

**GRAPHIC NOT
REPRODUCIBLE**

Hungary. Station No.
1113, Baja. Station
worker K. Stutó.
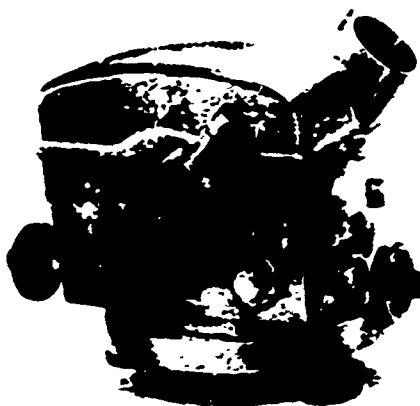
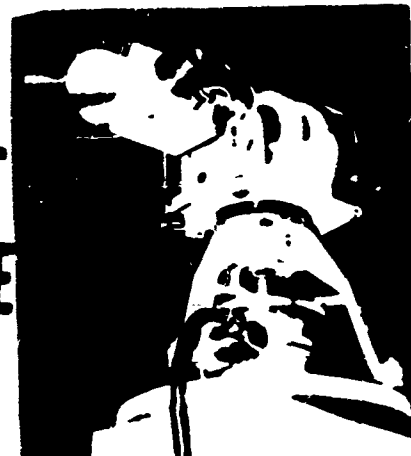Cuba. Station No. 1752, Cacaual. On the observation platform.

France. Station No. 3104, Strasbourg. K-37 camera for satellite photography.

Finland. Station No. 1963, Jokioinen. Recording theodolite.

France. Station No. 3101, Meudon. ASTRO II theodolite.

Hungary. Station No. 1114, Miskolc. Improved TZK telescope with photographic circle reading.

Czechoslovakia. Camera for satellite tracking prepared by the Geodetic Institute in Prague.